Dynamics of Josephson Vortices in Layered Superconductors

Scientific Achievement

In layered superconductors, such as $Bi_2Sr_2CaCu_2O_8$ (BSCCO), a magnetic field applied along the layers generates Josephson vortices (JVs). The JV lattice exhibits very rich dynamic behavior and has strong potential for high-frequency applications. We investigate theoretically and experimentally the static and dynamic properties of the JV lattice. We studied the influence of pancake-vortex stacks on JV dissipation. The JV voltage is extremely sensitive to a very small concentration of pancake-vortex (PV) stacks introduced by the c-axis component of a magnetic field. The excess current due to PVs depends nonmonotonically on voltage due to the finite PV relaxation frequency. This leads to voltage jumps in the current-voltage characteristics and an angular dependence of voltage measured at a fixed current. We developed a theory which explains the magnetic oscillations of the critical current and vortex-lattice structures in mesoscopic BSCCO mesas. Depending on the lateral size of the Josephson junction and the magnetic field, oscillations may occur with either the period of half a flux quantum per junction (wide-stack regime) or one flux quantum per junction (narrow-stack regime). For junctions with lateral sizes of the order of several Josephson lengths, a crossover between these regimes takes place with increasing magnetic field.

Significance

JVs generate a powerful traveling electromagnetic wave with the frequency proportional to the voltage. Furthermore, due to small dissipation, the JVs can be accelerated to very high velocities with a transport current. This quality holds great promise for using the moving JV lattice as a *tunable source for generating electromagnetic waves in the terahertz regime*. However, two fundamental challenges exist: to prepare a stable coherently moving lattice at high velocities and to launch the generated wave outside the sample. To address these challenges, we plan to study (i) surface electromagnetic radiation facilitated by artificially fabricated gratings, (ii) steady states and their stability in small-size mesas, and (iii) synchronization of oscillations in different layers by an external electromagnetic wave.

Performers

A. Koshelev, U. Welp, K. Gray, T. Tachiki, C. Kurter, V.Vlasko-Vlasov, W. K. Kwok, G.W.Crabtree (ANL-MSD)

M. Tachiki, K. Kadowaki (Univ. of Tsukuba, Japan), Yu. Latyshev (IREE, Moscow, Russia), L. Bulaevskii (LANL), L.Ozyuser (Izmir Institute of Technology, Turkey)

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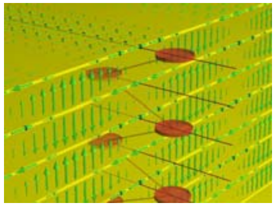
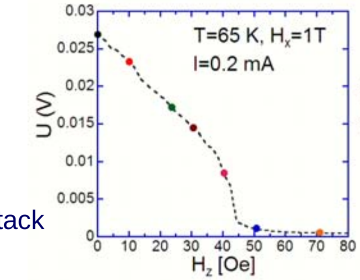
Motivation

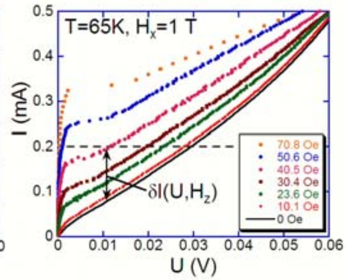
- Low dissipation of Josephson vortices
  → can move at very high velocities
  → source of powerful electromagnetic wave
- Potential for high-frequency applications
- Rich dynamic behavior



Zigzag deformation of PV stack by dense JV lattice



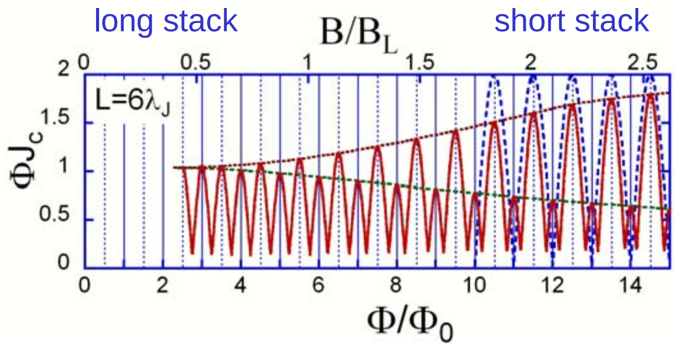
Dependence of Josephson flux flow on c-axis field



IVs at marked points

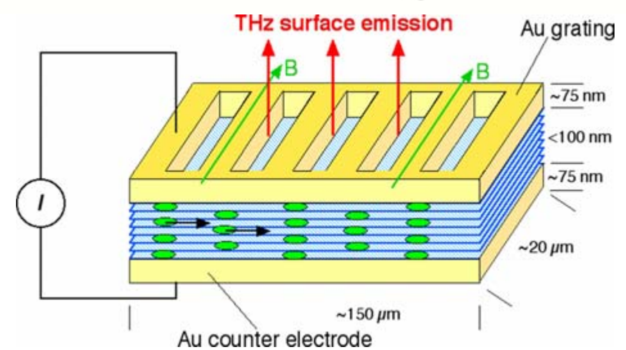
Recent Achievements

- Controlling dynamics of Josephson vortex lattice using pancake vortices
- Theory of magnetic oscillations in finite-size stacks



Future Directions

- Extraction of THz-radiation from BSCCO mesas using surface grating
- Theory:
  - Steady states and their stability in small-size stacks
    - Regions of rectangular lattice
  - Influence of fluctuating pancake stacks on dynamics of Josephson vortices



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Materials Science Division
ARGONNE NATIONAL LABORATORY

M. Tachiki, K. Kadowaki, Yu. Latyshev, L. Bulaevskii, L. Ozyuser